Argonne NATIONAL LABORATORY

Nanoelectrofuels for Flow Batteries

HIGH-DENSITY, RECHARGEABLE LIQUID FUEL

ILLINOIS INSTITUTE OF TECHNOLOGY

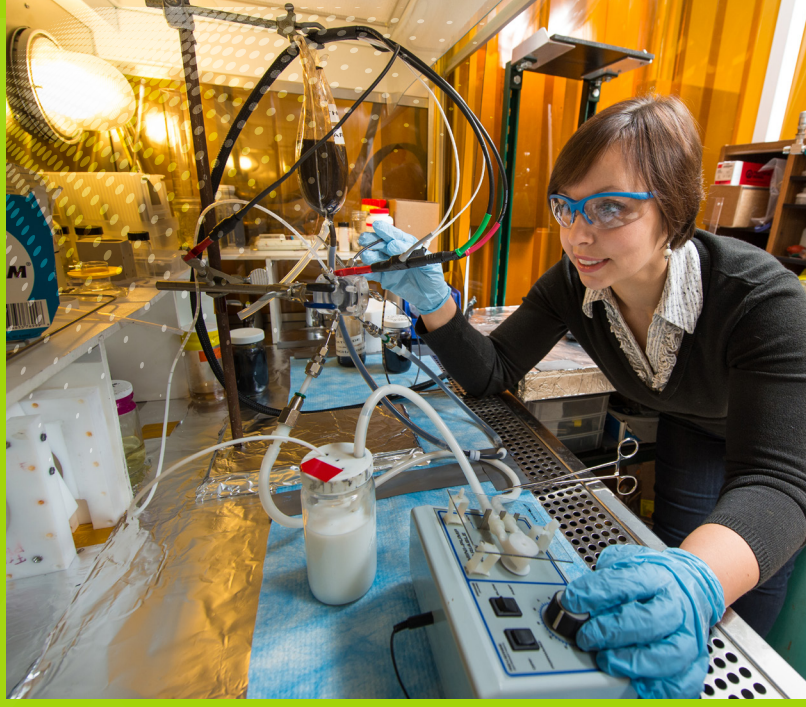
TINY YET POWERFUL PARTICLES

Nanoelectrofuels are a new type of nanotechnology-based high-energy-density liquid energy storage medium that can be used in combination with uniquely designed flow batteries.

Working together, scientists from the Illinois Institute of Technology (IIT) and Argonne National Laboratory developed a groundbreaking concept for the storage of electrical energy. Leveraging the properties of conventional solid state batteries, flow batteries and nanofluid technology, the team created unique formulations for cathodic and anodic nanoelectrofuels with high concentrations of active materials that are stably dispersed, exhibit liquid behavior in a wide range of temperatures and offer excellent flow and pump performance. A unique flow battery cell design was also developed to accommodate the effective charge and discharge of nanoparticles in suspension.

The nanoelectrofuel technology offers a host of other benefits, including

- Superior heat transfer capabilities
- Separation of the power and energy components (size of the flow cell stack vs. volume of nanoelectrofuel storage)



- Rapid return to a fully charged state through re-pumping
- Long cycle life
- Low maintenance
- Tolerance for overcharging or overdischarging

The use of nanoelectrofuel in this high-energy-density flow battery offers fertile ground for scientific exploration across many disciplines, and promises to revolutionize the practice of energy storage.

NANOELECTROFUELS EXCEED CRITICAL PERFORMANCE FACTORS FOR ENERGY STORAGE

Attribute	Stationary Power	Transportation	Nanoelectrofuel
Cost per kWh	Less than $100 needed	Less than $250 needed	$80
Energy density	25-35 Wh/kg	Up to 200 Wh/kg	Up to 600 Wh/kg

A HIGHLY FLEXIBLE SYSTEM

The combination of nanoelectrofuels and unique flow battery cells increases the specific energy density of flow batteries to and above that of solid-state lithium-ion batteries, creating an attractive energy storage medium for any industry or application that relies on stable energy storage for its operations. A liquid energy storage medium (nanoelectrofuel) separate from the energy extraction device (flow cell stack) enables the separation of charging and the long-term storage of charged nanoelectrofuels, resulting in improved and more effective energy distribution routes from power plants to customers.

The stability, high-energy density, efficiency and relative low cost of this cutting-edge innovation make it a good choice for numerous industrial design options. It will be especially useful in the following applications:

- Transportation (rechargeable liquid storage for electrical and hybrid electrical vehicles, fast refueling)
- Stationary power storage, including
  - Grid leveling (battery systems for large-scale load-leveling and local back-up systems)
  - Renewables (efficient storage and distribution of energy from intermittent wind and solar plants)
  - Military devices (concentrated energy, fast response, easy maintenance)

KEY BENEFITS

THERMAL SAFETY

Battery safety in electric vehicles is a key concern. The superior heat transfer capabilities of nanoelectrofuel make flow batteries an eminently safer choice for electric vehicles than those currently in use.

DESIGN FLEXIBILITY

The system lends itself to an almost infinite number of design options. It offers variable power and energy density ratings with storage tanks of any shape positioned however needed with respect to the flow cell stack.

HIGH-ENERGY-DENSITY, RECHARGEABLE

Nanoelectrofuel-powered flow batteries offer more than 10 times greater capacity than conventional flow batteries. Because of nanoscale sizes and custom modification of nanoparticle surfaces, nanoelectrofuels exhibit fast response, high charge/discharge efficiency and an extended fuel cycle life.

STABLE, PUMPABLE AND TRANSPORTABLE

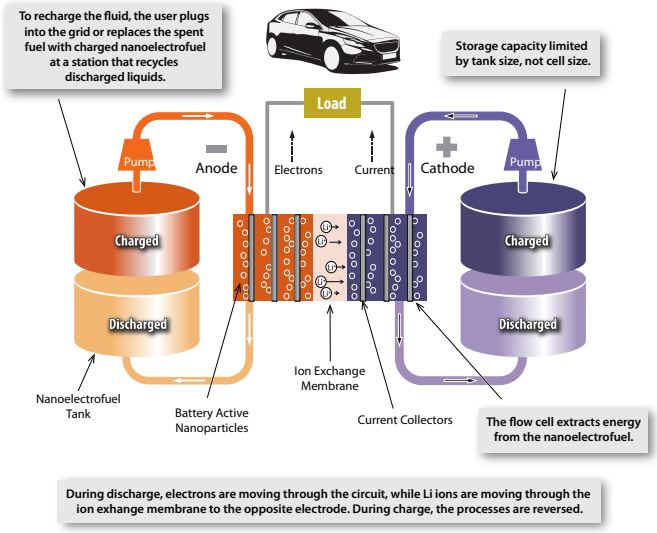
Nanoelectrofuel's pumpable liquid behavior and chemical stability offer effective distribution of charged nanoelectrofuels from power plants to customers (omitting the grid), use of the same nanoelectrofuel in multiple devices (for example, in electric vehicles and house back-up systems) and fast refueling of electric vehicles.

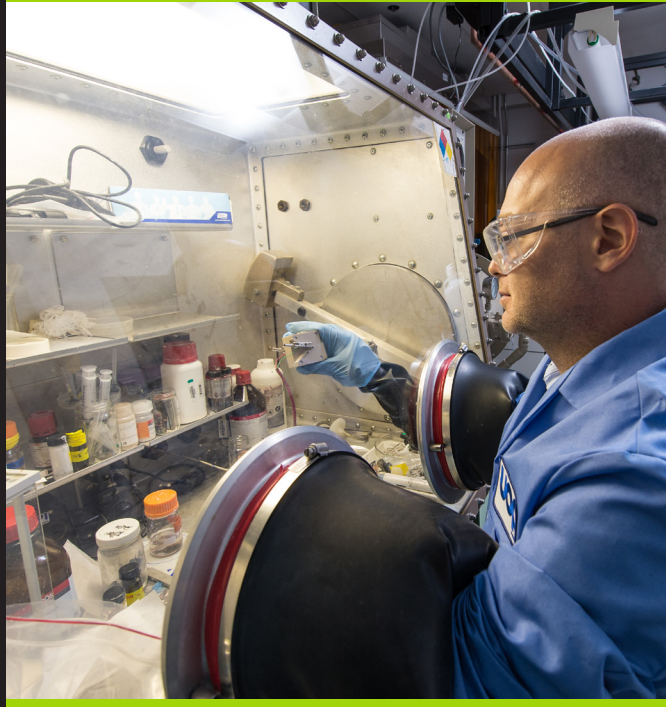
SMALLER FOOTPRINT

Nanoelectrofuel enables powerful stationary installations on an order-of-magnitude smaller footprint.

ENVIRONMENTALLY FRIENDLY

Nanoelectrofuels are recyclable and sustainable, and can be manufactured domestically without complex assembly or sealed packaging. The technology offers an easy way to separate electrode materials from other battery components for disposal or recycling.





HOW IT WORKS

The flow battery uses two nanoelectrofuels—one anode and one cathode fuel—that are stored externally to the flow cell and can be charged or discharged while passing through the cell in a closed circuit. The unique flow battery cell is designed to efficiently operate with rechargeable nanoelectrofuels. A novel flow-through electrode uses inexpensive conductive inert materials.

Using in-situ X-ray adsorption spectroscopy (XAS), the IIT-Argonne research team demonstrated effective charging of nanoelectrofuels. Researchers prepared electroactive nanofluids by dispersing battery anode nanoparticles and comparing the results against in-situ XAS of the same electroactive nanoparticles in conventional solid state batteries. XAS results combined with electrochemical characterization of the anode material indicate charging/lithiation of unsupported nanoparticles in suspension similar to the lithiation of the electrode nanoparticles in solid state batteries.

RESEARCH WINS $3.44M ARPA-E GRANT

The IIT/Argonne team has won a three-year, $3.44 million grant from Advanced Research Projects Agency-Energy (ARPA-E), a government agency that funds research and development of advanced energy technologies. The award was one of 22 granted to projects across 15 states focused on innovations in transformative electric vehicle energy storage. The funding will allow the construction of a 1 kWh nanoelectrofuel flow battery prototype scalable for electric vehicle needs.

DEVELOPMENTAL STAGE

This technology is available for licensing.

FOR MORE INFORMATION, CONTACT

Argonne Technology Development and Commercialization

partners@anl.gov | 800-627-2596

Technical Contact

Elena V. Timofeeva | etimofeeva@anl.gov

U.S. DEPARTMENT OF ENERGY